Molten Salt Reactor Development

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Oak Ridge Tennessee

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Why Nuclear?

- **Energy density**
- Low-carbon electricity
- National energy security
- Diverse energy portfolio

- PB-FHR fuel pebbles
  - **Four 3.0-cm diameter pebbles** can provide electricity for a year for an average U.S. household
  - **8.1 tons** of anthracite coal, or **17 tons** of lignite coal are needed to produce the same amount of electricity using a coal power plant.
Why Advanced Reactors?

– Better safety posture
– Lower costs
– Reduced accident consequences
– Expanded siting options
– Better resource utilization
– Ability to close the fuel cycle
– Reduced waste products
Why MSRs?

• **High-temperature, low-pressure** systems with chemically **inert fluids**
  – Lower-cost components
  – Dry heat rejection capability

• Large **temperature margins to boiling**
  – Passive safety response
  – Fewer safety critical systems

• Large **baseload** or **small modular** deployment

• **Continual salt and fission product** processing possible
  – Reduced emergency planning zone (?)
  – Ability to use UNF
  – Ability to help close the fuel cycle and reduce waste to repositories
MSR Passive Safety: The Freeze Plug

- In the event of TOTAL loss of power, the freeze plug melts and the core salt drains into a passively cooled configuration where nuclear criticality is impossible.

- The reactor is equipped with a “freeze plug”—an open line where a frozen plug of salt is blocking the flow.

- The plug is kept frozen by an external cooling fan.
MSRs are a broad class of advanced reactors

• MSRs are *revolutionary* for the implementation of nuclear power
• MSRs can *revitalize* the U.S. nuclear energy sector
• MSRs are *near-term* innovations
How do you get into a market?
Sell a product or provide a service

• Either
  – Produce *cost-competitive electricity* or *industrial heat*
    • Lower capital cost
    • Lower O&M costs

• Or
  – Play a positive role in *closing the fuel cycle*

• Or
  – Uniquely meet the needs of a *niche market*
    • *High quality heat*
    • “expensive” power for special applications
What do we need to get MSRs to market?

- **Materials**, salts, and an understanding of their behavior
- Enabling **technology**
- Design **rules** and standards
- Reactor **designs** and **mod-sim methods** to effectively evaluate their performance
- A convincing story of reactor **safety** and **source term management**
- Understanding and agreements about ultimate **waste** forms
- A **business** case for the concept
- A well-defined path for **licensing** of the first reactors
- A follow-on path for licensing **commercial** reactors
- Interested **investors** and a **supportive government**
- **Supply chains** and supporting **infrastructure**
- Initial **fuel** core loadings
New Chemistry and Reactor Modeling Challenges

- **Understand reactor performance and behavior**
  - Develop and integrate *dynamic salt chemistry models* with neutronic and thermal hydraulic analyses for reactor performance evaluation all the way through severe accident transients

- **Understand source term behavior**
  - Develop *constituent lifecycle data* and models to account for *source term behavior*
DOE MSR FY18 Priorities

- Materials and salt combinations and their interactions
- Salt chemistry data, database, and chemistry models
- Enabling technology
- Concept evaluation
- Modeling and simulation
- Licensing and safeguards
- Salt processing, reuse, and waste forms
Which Molten Salt Reactors are we interested in?
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• All of them
  • “if you’re interested in it, we’re interested in it”
• The market needs diversity
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- Our job is to facilitate an environment in which new reactors can be developed
- We are not designing a DOE reactor or picking winning designs
Each concept requires acceptable materials and salts.

Temperature Driven Cyclic Corrosion Process is the Limiting Corrosion Factor.

\[ \Delta T = \text{Hot Leg} - \text{Cold Leg} \]

\[ \text{Oxidant} + \text{Cr} = \text{Reductant} + \text{CrF}_2(d) \]
\[ 2\text{UF}_4(d) + \text{Cr} = 2\text{UF}_3(d) + \text{CrF}_2(d) \]

Initial impurity-driven corrosion

Persistent Cyclic Corrosion Mechanism (slope proportional to U-content)
Each concept needs a “Cradle-to-Grave” plan
We’ve got to do something soon
(M. Herald and M. Adkisson)

Projection showing the loss of nuclear capacity in the southeast U.S.
DOE is taking a focused, near-term development approach to reactor development and deployment

- Science
  - Technology
    - Development
      - Demonstration
- Salts, materials and their interactions
  - Components, processes, systems
  - Reactor concepts
  - Engineering scale testing
- First reactors
- Licensing and Safeguards
- Next reactors

~10 years

~15 - 20 years
Notional Timeline to MSR Deployment

- Materials and salt selection
- Salt processing and manufacturing
- Salt and material corrosion studies
- Reactor concept development
- Materials qualification
- Enabling technology development
- Source term characterization and behavior
- Reactor performance evaluation
- Licensing framework development
- Test reactor design, construction, and operation
- Prototype reactor design and operation
- Commercial plant design and construction
- Commercial plant deployment
Molten Salt Reactor Experiment

- **Timeline**
  - Salt loaded into tanks - **Oct. 24, 1964**
  - Salt first circulated through core - Jan. 12, 1965
  - **First criticality (U\textsuperscript{235}) - June 1, 1965**
  - First operation in megawatt range - Jan. 24, 1966
  - Full power reached - May 23, 1966
  - Nuclear operation with U\textsuperscript{235} concluded
  - Strip uranium from fuel salt - Aug. 23-29, 1968
  - First criticality with U\textsuperscript{233} Oct. 2, 1968
  - Full power reached with U\textsuperscript{233} Jan. 28, 1969
  - Nuclear operation concluded - Dec. 2, 1969
Questions?

Thank you